Johnson Space Center Procedural Requirements

JPR No.:	5335.4
Effective Date:	12/14/2006
Expiration Date:	12/14/2011

VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

COMPLIANCE IS MANDATORY

Statistical Techniques for Product Acceptance

Responsible Office: EA/Engineering Directorate

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Change History Log

Revision	Effective Date	Description of Changes
Baseline	10/01/2006	Initial Release

Preface

P.1 PURPOSE

This Johnson Space Center Procedural Requirement (JPR) provides a method for applying statistical techniques used in data analysis or interpretation for establishing, controlling, and verifying process capability and product characteristics during receiving inspection, when 100% inspection or test is not possible or appropriate.

P.2 APPLICABILITY

This JPR is applicable to any engineering or non-engineering organization procuring critical and complex hardware, components, or piece parts, excluding raw materials, where receiving inspection or test is performed on less than 100% of all procured hardware. When an inspection sample size is less than 100%, valid statistical techniques shall be employed as instructed herein. It is noted that occasionally when apparent 100% sampling is used, the use of statistics may be implied. It is also noted that matching sampling rates to the criticality of the product and to the process capability is an important aspect in determining what level of statistical sampling should be used or whether statistical sampling is appropriate at all.

This JPR does not apply to acceptance sampling plans for Raw Materials, Batteries, or Pyrotechnics. Battery and Pyrotechnic sampling techniques for acceptance are documented in their respective procedures, reference NSTS 8060 Space Shuttle System Pyrotechnic Specification, JSC 62809 Constellation Spacecraft Pyrotechnic Specification, and JPR 8080.5 Batteries section. Raw Materials sampling techniques for acceptance are documented in JPR 5335.6.

P.3 AUTHORITY (All document citations are assumed to be the latest version unless otherwise noted.)

JPD 5335.3 Quality Manual

P.3 APPLICABLE DOCUMENTS (All document citations are assumed to be the latest version unless otherwise noted.)

JPR 5335.3 Quality Manual

Juran's Quality Control Handbook -- refer esp. to sections on "Basic Statistical Methods – Sources and Summarization of Data" and "Acceptance Sampling"

ANSI/ASQ Z1.4 Sampling Plans for Attributes

ANSI/ASQ Z 1.9 Sampling Plans for Variables

JPR 8080.5 JSC Design and Procedural Standards

JSC23642 JSC Fastener Integrity Testing Program

JSC 49879 JSC Wire & Cable Integrity Compliance Program

JSC 62809 Constellation Spacecraft Pyrotechnic Specification

NSTS 8060 Space Shuttle System Pyrotechnic Specification

NT-PQE-012 Attributes Sampling Plan for Manufacturing Inspection

NT-QAS-016 Screening Sampling and Storage Control of Liquids

P.5 MEASUREMENT VERIFICATION:

Internal audits will verify that this JPR is being appropriately implemented.

P.6 CANCELLATION/RECISSION:

No documents are cancelled or replaced by this directive.

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Statistical Techniques for Product Acceptance

October 2006

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12/14/2006

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Orginal signed by: 12/8/06

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Chapter 1 - Definitions

1.1 Acceptable Quality Level (AQL) – acceptable reject rate necessary to accept a lot based on statistical sampling data.

1.2 Attributes – a characteristic or property that is appraised in terms of whether it does or does not exist with respect to a given requirement.

1.3 Critical and Complex Hardware – A deterministic, subjective attribute applied to specific hardware in accordance with the guidance herein described.

1.4 Design of Experiments (DOE) – the arrangement in which an experimental program is to be conducted and the selection of the levels of one or more factors or factor combinations to be included in the experiment.

1.5 Process Capability – is the total inherent variation that can be expected from the process over a long period of time.

1.6 Procuring Organization – The organization that generates a requirement for hardware purchase.

1.7 Raw Material – Material before being processed or manufactured into a final form.

1.8 Receiving Organization – The organization, sometimes called the accepting or acceptance organization, responsible for receiving inspections or defining receiving inspection requirements for a given hardware purchase, not necessarily the procuring organization.

1.9 Sampling Plan --a specific plan that states the sample size or sizes to be used, and the associated acceptance criteria.

1.10 Statistical Process Control (SPC) – is the use of statistical techniques and tools to measure an ongoing process for change or stability.

1.11 Statistical Techniques (ST) -- Mathematical techniques used to interpret data.

1.12 Statistical Techniques User (STU) -- Any individual(s) who is responsible for performing Statistical techniques to establish, verify, and control process capability and product Characteristics.

1.13 Variables -- a measurable factor, characteristic, or attribute of a component or a system whose measurement may be different between samples; something that might be expected to vary over time or between individuals.

Chapter 2 - Responsibilities

2.1 JSC organizations procuring critical and complex hardware, components, or piece parts, where receiving inspection or test is performed on less than 100% of all procured hardware shall be responsible for:

2.1.1 identifying the requirement to use and/or the appropriateness of the use of statistical techniques for acceptance,

2.1.2 determining if the organization has the capability needed to plan for and/or perform an analysis,

2.1.3 contacting the Quality and Flight Equipment Division (NT) if assistance is needed,

2.1.4 implementing and controlling the application of the statistical techniques, and

2.1.5 requesting the appropriate use of statistical techniques in contracted work.

2.2 The statistical techniques user (STU) shall be responsible for identifying required and/or appropriate statistical techniques and methods, applying the appropriate techniques to the data, issuing reports on the results of the statistical techniques, recording any statistical methods used, and recording any statistical sampling plan used.

2.2.1 If a specially published or mandated statistical procedure is used, reference to that procedure shall be noted by the STU in the appropriate permanent record of any analysis. As an example, if a sampling plan is constructed using ANSI/ ASQC Z1.9, reference to that document shall be preserved within the analysis record.

2.2.2 If a sampling plan is developed, it shall be tied by the STU either to an established document that circumscribes the method used to develop the plan or to a reasonable and statistically acceptable method from which the plan is derived. The document or method used shall be recorded within the sampling plan.

2.2.3 If the lot testing and lot inspection cannot conform to standard methods of sampling and statistical analysis, Appendix D should be consulted to develop a unique, documented, well reasoned sampling plan that meets the spirit and intent of the standard methods.

Chapter 3 - Procedure

Actionee	Action
JSC Procuring Organization	3.1 Identifies a requirement for the use of statistical techniques for acceptance testing and inspection when critical and complex hardware is procured.
JSC Procuring Organization	3.1.1 Determines what hardware is categorized as Critical and Complex based on criteria set by the associated JSC procuring organization's subject matter experts.
STU or STU with NT	3.2 Develops a sampling plan for data collection and analysis. This may include identifying any required or mandated analyses such as those required by Work Instructions (WIs), plans, procedures, external references, etc. and planning to control those data and their analyses. This will often include choosing other specific analysis tools and constructing a data collection plan to accommodate this (DOE, AQL, sample size determination, etc.). This may comprise simply choosing an appropriate statistical technique necessary to analyze the data such as the techniques specified by industry standards ANSI/ASQC Z1.4 or Z1.9. Note that this step, 7.2.1 and 7.2.2 sometimes follow 7.3.
JSC Procuring Organization	3.2.1 Where applicable, implement and control the statistical techniques applied using WIs, plans, procedures, external references, etc.
JSC Procuring Organization with NT	3.2.2 Where statistical techniques are not practical or possible due to hardware availability or other product

	related limitations, document in the sampling plan the exact rationale for not following a statistical approach and rigorously describe the decision process used for determining the sampling techniques that will be employed for acceptance. When a non-statistical approach is proposed, receive approval from that JSC procuring organization's senior manager or their delegate with concurrence from NT. (One example alternate sampling technique is described in Appendix D.)
STU	3.3 Identify and collect the necessary data.
STU or STU with NT	3.4 Perform the statistical analysis on collected data using the appropriate statistical techniques.
STU or STU with NT	3.5 Interpret the results from the statistical techniques.
STU	3.6 Generate reports to document data collected, statistical techniques used, and final results.

Chapter 4 - Flow Diagrams

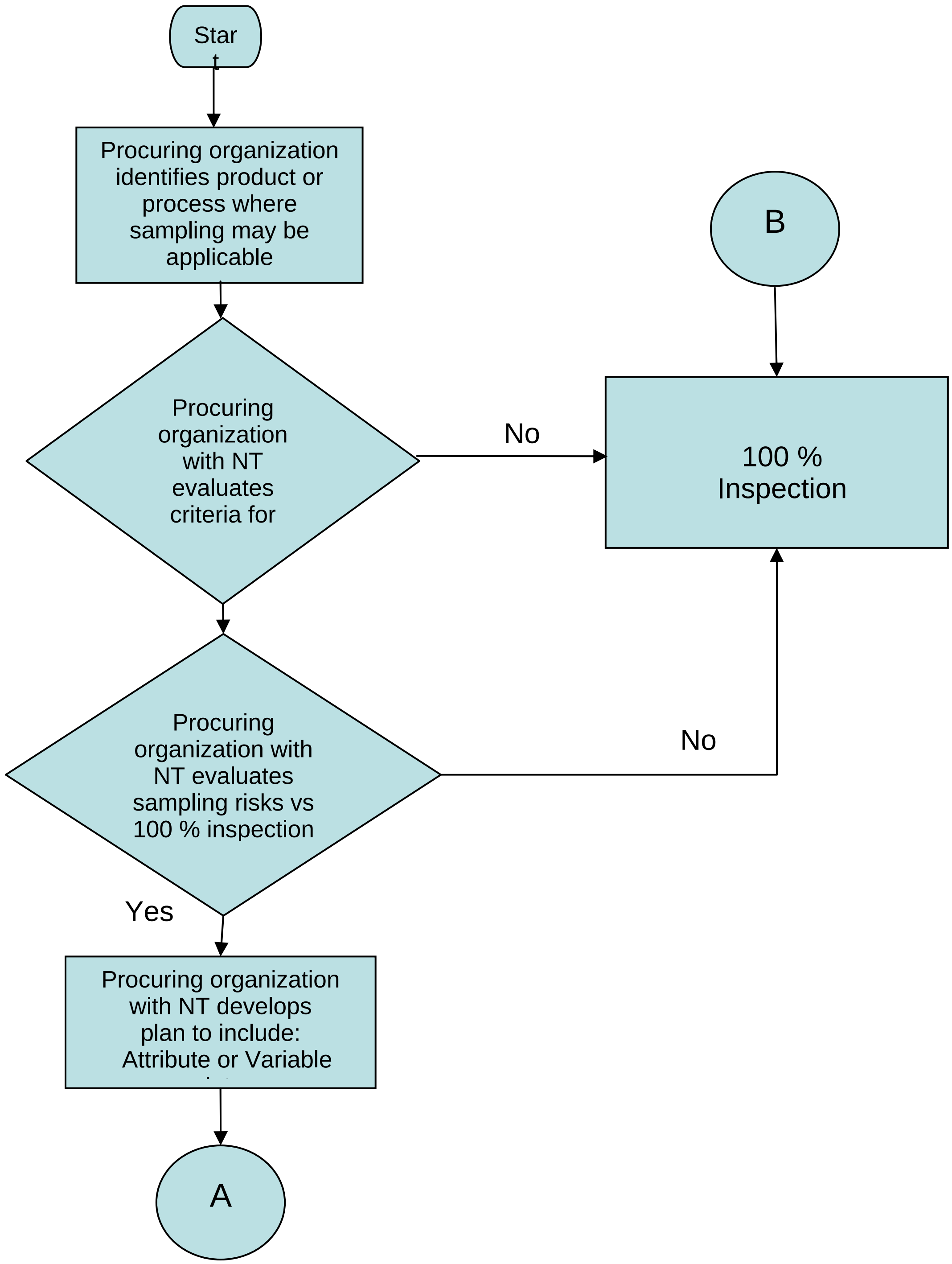
The statistical techniques process flow chart is shown in appendix A. This flow follows the steps described in section 7.0 above where the sampling plan must document the type of data to be collected.

The decision chart for statistical process control charting is shown in appendix B. Once it is determined what type of sampling data will be required, attributes or variables, this chart shows how to decide which chart within Z1.4 or Z1.9 to use for lot acceptance.

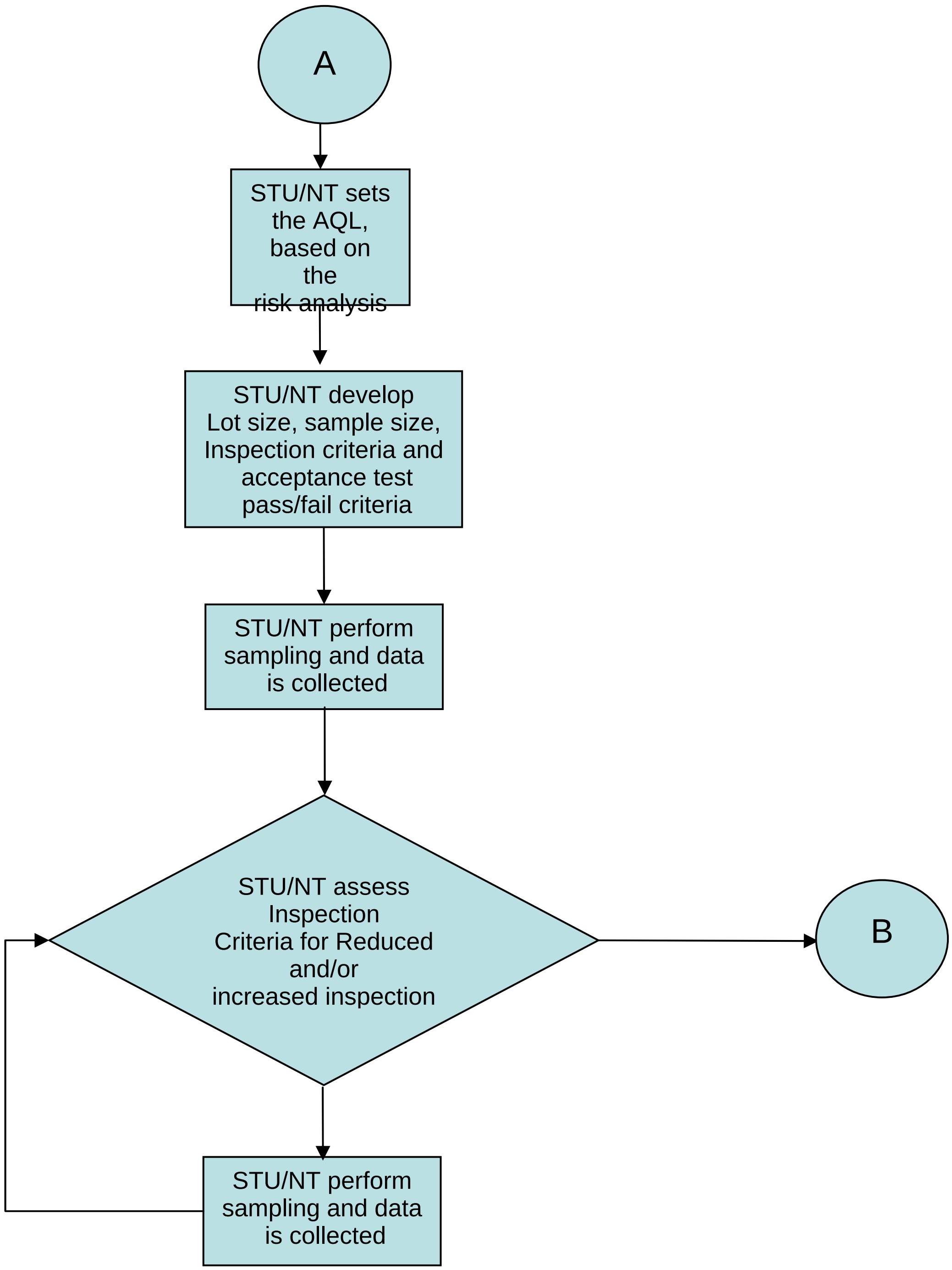
The switching rules for ANSI Z1.4 flow is shown in appendix C. Here the decision flow for either increased or reduced sampling is presented. Once initial samples are taken, the STU may decide to either reduce or increase the sample rate based on initial test result passing rates.

One example alternate sampling technique is described in Appendix D. When sampling is required but cannot conform to a statistical approach, the example decision matrix and explanation in appendix D may be used.

Appendix A
Statistical Techniques Process Flow Chart

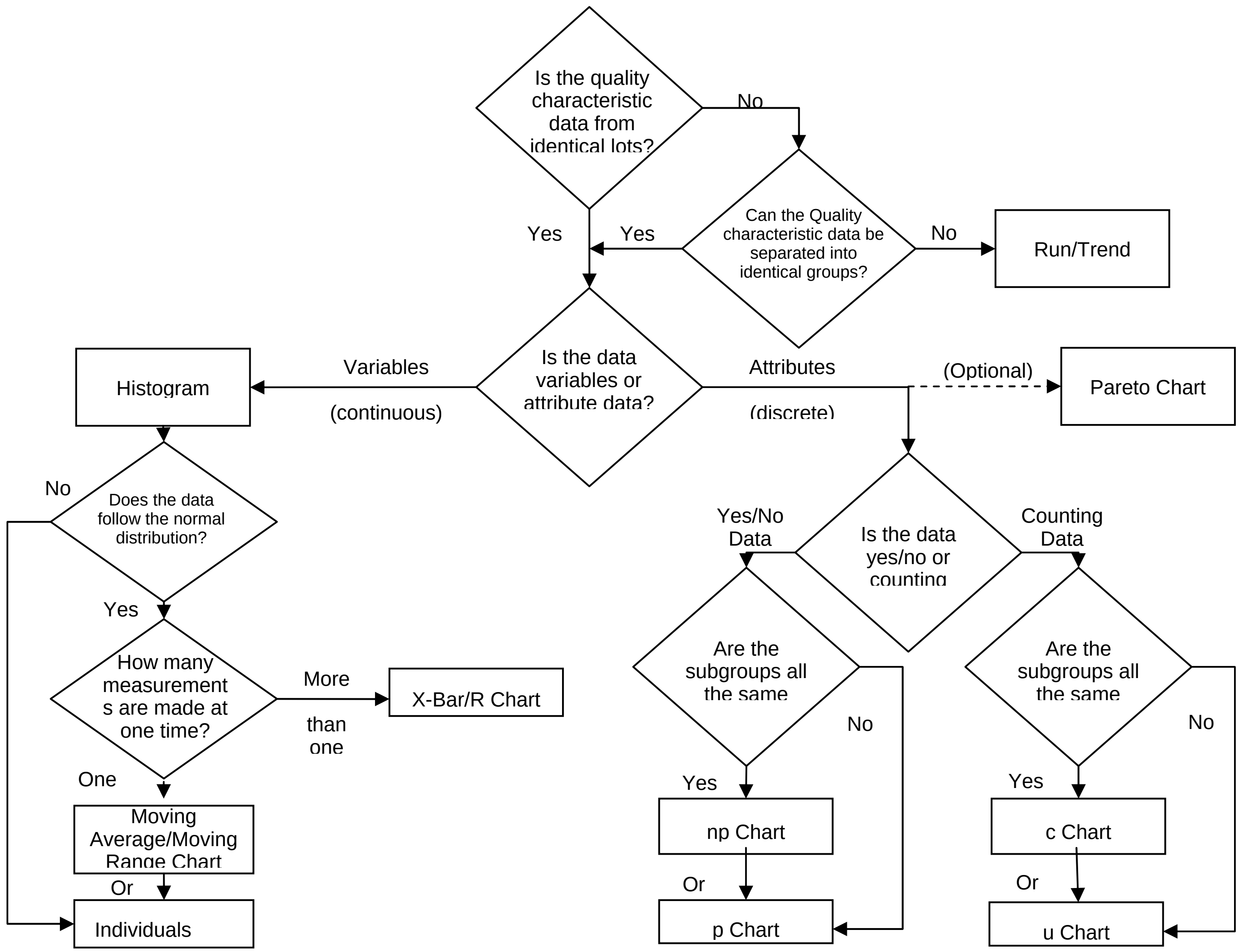


Appendix A (cont.)
Statistical Techniques Process Flow Chart



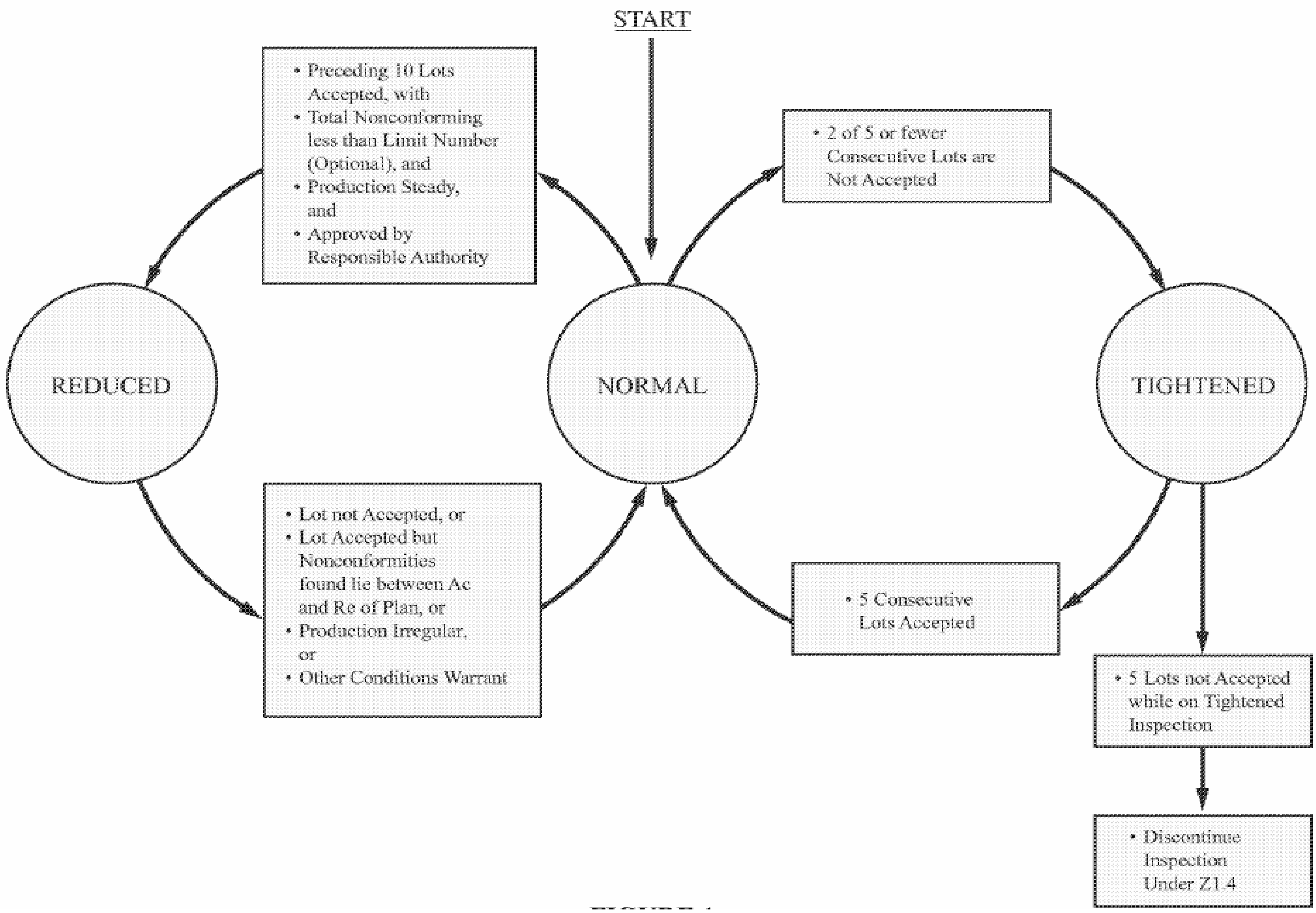
Appendix B
Decision Chart for Statistical Process Control Charting

Excerpted from American Society for Quality document number ANSI Z1.4



Appendix C

Switching Rules for ANSI Z1.4 System



Appendix D

Suggested Guidelines for Documenting Unique Sampling Plans for
Lot Testing and Lot Inspection (With Examples)

Purpose:

Some lot testing and lot inspection that involves sampling and statistical analysis cannot conform to standard methods of sampling and statistical analysis. These unique tests must have a unique, documented, well reasoned sampling plan. This Appendix provides a guideline for documenting a unique sampling plan.

Applicability:

A unique sampling plan must be developed when standard processes cannot be implemented or are not appropriate. Some example reasons include:

- Testing is destructive
- Hardware quantity is limited
- Test limitations restrict duration or amount of testing
- Sample lot size is too small

Required Elements of a Unique Sampling Plan:

Any unique sampling plan must have the following elements clearly documented:

- The rationale for using a unique sampling plan
- A hardware description (the hardware must be described in sufficient detail for someone unfamiliar with the hardware to understand the rationale)
- An assessment of uncertainty
- An assessment of the consequences of unrepresentative sampling leading to unrepresentative test results
- A description of the testing or inspection
- The sampling plan, including the following elements:
    - Lot size
    - Amount sampled
    - Pass / Fail criteria
    - Rationale for selecting this sampling plan

See the following example template:

Unique Sampling Plan for Lot Testing and Inspection
(Example Template)

Project:
Date:
Sampling Plan Developer:

Uncertainty				
	High			
	Medium			
	Low			
		Loss of Function	Loss of Mission	Loss of Life
		Consequence		

1.0 Hardware Description
- 1.1 Hardware Function
- 1.2 Hardware Components

2.0 Rationale for using a Unique Sampling Plan

3.0 Assessment of Uncertainty
- 3.1 Lot Size
- 3.2 Number of Units at NASA
- 3.3 Number of Total Units
- 3.4 Assessment of Hardware Variability

4.0 Assessment of Consequence
- 4.1 Mechanisms of System Failure
- 4.2 Assessment of Severity of Consequence

5.0 Description of Testing and Inspection Methods
- 5.1 Test Objectives
- 5.2 Test Methods
- 5.3 Limitations to 100% Sampling

6.0 Sampling Plan
- 6.1 Lot Size
- 6.2 Amount Sampled
- 6.3 Pass / Fail Criteria

6.4 Rationale for Sampling Plan

Three Examples of Unique Sampling Plans:

To serve as a guideline, three examples of unique sampling plans are attached. Three examples cannot be comprehensive, but they present a broad array of issues that affect many projects.

The first example describes a case where clear documentation emphasizes that the purpose of the testing is not to screen for hazards but to verify system performance, and to document the trade between statistical rigor and diminishing flight resources.

The second example documents two issues common at JSC. First, the system tested is entirely new, the hardware was developed in-house and has no precedent. Second, the test has constraints to sampling (the system involves matching a color to a reference card and the color changes with time – so the test cannot support more than 5 witnesses evaluating the color).

The third example documents a case where the NASA lot size if very small compared to the commercial data base. This documents a sampling plan intended to confirm configuration, and it documents a case where the uncertainty of the test itself is greater than the uncertainty of the hardware.

Unique Sampling Plan for Lot Testing and Inspection
Example #1

Project: BOCS oxygen candles
Date: 6/15/06
Developer: John Graf, EC X39226

Uncertainty				
	High			
	Medium		X	
	Low			
		Loss of Function	Loss of Mission	Loss of Life
			Consequence	

1.0 Hardware Description
 1.1 Hardware Function
 High temperature thermal decomposition produces oxygen. The chemistry is thermally self regulating (high temps quench reaction rates), but the nominal operations involve temperatures of 1100 – 1300 degrees F, and 100% oxygen levels at 1 atmospheric pressure
 1.2 Hardware Components
 The chemical briquette is manufactured as a single piece, the chemical starter is mixed and pressed (each component is weighed individually). All metal components are made of Monel
2.0 Rationale for Using a Unique Sampling Plan
 The test is destructive, and there is a limited supply of hardware. Each acceptance test reduces the on – orbit hardware capability. The test is not used to control a hazard, it is used to verify performance.
3.0 Assessment of Uncertainty
 3.1 Lot Size
 40 Monel units made as a single production run witnessed by DCAA inspectors
 3.2 Number of Units at NASA
 40 Monel Units at NASA (10 stainless steel commercial units at NASA)
 3.3 Number of Total Units
 5000 units produced of stainless steel configuration (used for submarines)
 3.4 Assessment of Hardware Variability

100% inspection of packing configuration
100% inspection of welds
100% inspection of seal and system leakage
100% inspection of component weights

4.0 Assessment of Consequence

4.1 Mechanisms of System Failure

Foreign object contamination, Failure to function due to system getting wet, failure to function because system does not ignite

4.2 Assessment of Severity of Consequence

Use of monel everywhere and 100% inspection provides the primary controls for fire hazards. Testing is focused of system function and oxygen production. Failure to produce oxygen leads to loss of mission

5.0 Description of Testing and Inspection Methods

5.1 Test Objectives

System igniting, system producing specified amount of oxygen

5.2 Test Methods

Ignite system in flight configuration, determine ignition, measure oxygen production, measure unit temperature in 7 places

5.3 Limitations to 100% Sampling

This is a destructive test. Units cannot be used after they have been tested. Lot size is limited to 40 and each candle tested limits useful inventory

6.0 Sampling Plan

6.1 Lot Size

40 units

6.2 Amount Sampled

10 total tests (7 with commercial system, 3 with monel unit)

6.3 Pass / Fail Criteria

Does system ignite, does system produce specified oxygen

6.4 Rationale for Sampling Plan

3 of 3 and 10 of 10 balances inventory with test needs. Understanding of system variability based on temperature trends and oxygen production levels.

Unique Sampling Plan for Lot Testing and Inspection
Example #2

Project: Gold Salt Hydrazine Detector
Date: 6/15/06
Developer: John Graf

Uncertainty			
High			
Medium		X	
Low			
	Loss of Function	Loss of Mission	Loss of Life

Consequence

1.0 Hardware Description
  1.1 Hardware Function
  Hardware used to screen for hydrazine in the airlock prior to EVA egress. Units custom developed by NASA, not commercially available, not widely used in the field. Hardware uses a color change reaction chemistry based on fuel/oxidizer reactions. Chemistry does not suffer ammonia interference
  1.2 Hardware Components
  System consists of a sampling adapter that connects to the hatch depress valve, chemical coupons, and a color reference card. Chemical coupons may fail if pre-contaminated
2.0 Rationale for Using a Unique Sampling Plan
  This is new hardware without precedent. Primary controls are fabrication process. The objective of the test is to verify system performance. The test is destructive, the hardware cannot be used after testing. The uncertainty and variability of the testing is greater than the uncertainty of the hardware.
3.0 Assessment of Uncertainty
  3.1 Lot Size
  200 coupons per custom NASA manufacture lot
  3.2 Number of Units at NASA
  200 coupons at the time of initial qualification
  3.3 Number of Total Units

200 coupons at the time of initial qualification

3.4 Assessment of Hardware Variability
Excellent reproducibility within the flight qualification lot (based on 30 engineering evaluation tests). No information about lot to lot variability because this is a new design

4.0 Assessment of Consequence

4.1 Mechanisms of System Failure
False negative reading could be due to contamination after lot acceptance. Because all coupons were made from the same sheet, variability of coupon is not a credible concern.

4.2 Assessment of Severity of Consequence
System failure (false negative reading) will not credibly lead to loss of life, because crew will detect unsafe levels of hydrazine by smell and don PPE, but a large undetected leak may require crew to consume all available PPE and be forced to abort mission

5.0 Description of Testing and Inspection Methods

5.1 Test Objectives
Evaluate chemical response and color change over the entire chemical concentration range required

5.2 Test Methods
Exposure of coupons to MMH in flight conditions (5 psia / flow through depress valve to vacuum). Perform color match evaluation by untrained human evaluators under shuttle lighting conditions (paint and light spectrum)

5.3 Limitations to 100% Sampling
This is a destructive test. Hardware cannot be used after it is tested.

6.0 Sampling Plan

6.1 Lot Size
Flight lot of 30 (limited by the quantity of Teflon sample holders)
Manufacture lot of 200 chemical coupons

6.2 Amount Sampled
25 units tested (5 different test points / 5 coupons each test)

6.3 Pass / Fail Criteria
4 of 5 human evaluators make the proper color match

6.4 Rationale for Sampling Plan
The color changes with time, and there isn’t time to have more than 5 evaluators. The biggest variation in the system is the human evaluator – the hardware could work perfectly and fail if a human makes a poor color match if 5 of 5 success criteria were used.

Unique Sampling Plan for Lot Testing and Inspection
Example #3

Project: Contamination Detection Kit (Draeger tube)
Date: 6/15/06
Developer: John Graf

Uncertainty	High			
	Medium			
	Low		X	
		Loss of Function	Loss of Mission	Loss of Life

Consequence

1.0 Hardware Description
   1.1 Hardware Function
      Hardware used for detection of ammonia in the airlock prior to EVA egress. COTS hardware adapted for flight safety and reduced pressure operations.
   1.2 Hardware Components
      Sample flow adapter that attaches to the airlock depress hatch and COTS draeger tubes that react with ammonia, change color, and are evaluated by a length of stain.

2.0 Rationale for using a Unique Sampling Plan
   The test is destructive, and hardware cannot be used after testing. The inventory at NASA is extremely small compared to the commercial sample size. The primary intent of the test is verification of configuration.

3.0 Assessment of Uncertainty
   3.1 Lot Size
      NASA buy lot is 50 (C of C from Draeger states tubes came from the same manufacture lot)
   3.2 Number of Units at NASA
      50 tubes
   3.3 Number of Total Units
      Greater than 100,000 total units sold

- 3.4 Assessment of Hardware Variability

  COTS product under tight configuration management with a simple design. Extremely small hardware variability.

4.0 Assessment of Consequence

- 4.1 Mechanisms of System Failure

  False negative reading most likely caused by the wrong acceptance test rather than hardware or test variability. Liquid water poisoning the most likely cause of a false negative
- 4.2 Assessment of Severity of Consequence

  Failure to detect will not credibly lead to loss of life, because crew will smell ammonia and don PPE. But a large undetected release of ammonia could cause loss of mission

5.0 Description of Testing and Inspection Methods

- 5.1 Test Objectives

  Measure detection level performance over the entire range of concentrations required. Determine sensitivity to sample flow time. Demonstrate hardware chemical interference capability.
- 5.2 Test Methods

  Expose tubes to ammonia in flight conditions (5 psia, flow through a depress hatch to vacuum), measure length of stain
- 5.3 Limitations to 100% Sampling

  Test is destructive, hardware cannot be used after testing

6.0 Sampling Plan

- 6.1 Lot Size

  50 tubes
- 6.2 Amount Sampled

  12 tubes (three tubes each in four test conditions)

  3 of 3 must pass each test
- 6.3 Pass / Fail Criteria

  Color change of the tube (length of stain)

  3 of 3 must pass
- 6.4 Rationale for Sampling Plan

  The intent of the test is to verify hardware configuration. The uncertainty of the test is greater than the uncertainty of the hardware. 3 of 3 provides assurance the test protocols and hardware are in proper configuration. .